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Money Creation under Full-reserve Banking: A Stock-flow Consistent Model*

by

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ABSTRACT

This paper presents a stock-flow consistent model[+] of full-reserve banking. It is found that in a steady state, full-reserve banking can accommodate a zero-growth economy and provide both full employment and zero inflation. Furthermore, a money creation experiment is conducted with the model. An increase in central bank reserves translates into a two-thirds increase in demand deposits. Money creation through government spending leads to a temporary increase in real GDP and inflation. Surprisingly, it also leads to a permanent reduction in consolidated government debt. The claims that full-reserve banking would precipitate a credit crunch or excessively volatile interest rates are found to be baseless.

Keywords: Full-reserve Banking; Stock-flow Consistency; Money Creation; Banking System

JEL Classifications: E27; E42; E51

[+] The model REFORM is available for download. The baseline scenario (the "old" steady state) is available at: www.patriziolaina.com/tiedostot/frb_steady_state.txt. The money creation experiment (the transition phase leading to the "new" steady state) is available at: www.patriziolaina.com/tiedostot/frb_money_created.txt. In order to run the programs a licensed version of EViews is required.

1. INTRODUCTION

Under full-reserve banking (FRB) private money creation is prohibited. Today it would mean that banks could no longer create new money in the form of bank deposits in the process of bank lending. FRB aims at separating the payments system from the financing system as well as monetary policy from credit policy.

After the global financial crisis, FRB became a topical issue as a potential solution to financial instability. It has been proposed, for instance, by a report commissioned by the prime minister of Iceland (Sigurjonsson 2015), an established columnist at the *Financial Times* (Martin Wolf 2014a; 2014b), and Positive Money (Jackson and Dyson 2012); however, many economists and commentators judge FRB (either positively or negatively) based on their prejudice rather than coherent analysis.

The specific contribution of this paper is to build a stock-flow consistent (SFC) model of FRB. FRB has not been previously modeled in a SFC framework popularized by Godley and Lavoie (2012). Previously, it has only been modeled in a dynamic-stochastic general equilibrium framework of neoclassical economics (Benes and Kumhof 2012, 2013), in a system dynamics framework (Yamaguchi 2010, 2011, 2014), and in a dynamic multiplier framework (Flaschel et al. 2010; Chiarella et al. 2011). The last of these three comes closest to SFC modeling being based on stocks and flows, but not in the same sense as in Godley and Lavoie (2012).

The SFC model of FRB built in this paper is called REFORM. It is developed from Godley and Lavoie's (2012) model INSOUT. The key features of REFORM are:

- Banks are required to hold central bank reserves in an amount equal to their demand deposits (full-reserve requirement).
- The central bank sets the amount of reserves by buying government bills.
- Households are the residual buyer of bills and, therefore, the bill rate is endogenous.
- Banks adjust the interest rate on time deposits to attract enough deposits to fund loans.

It is found that in a steady state FRB can accommodate a zero growth economy. In addition, both full employment and zero inflation are achieved.

Furthermore, this paper conducts an experiment with REFORM, in which money is created in a FRB system, and studies its consequences. An increase in central bank reserves translates into a two-thirds increase in demand deposits. Money creation through government spending leads to a temporary increase in real GDP and inflation. Surprisingly, it also leads to a permanent reduction in consolidated government debt. The claims that FRB would lead to a shortage of credit or excessively volatile interest rates are found to be baseless.

The paper is structured as follows. Section 2 presents the balance-sheet, revaluation, and transaction-flow matrices. Section 3 presents and explains the equations. Section 4 discusses the properties of the “old” steady state. Section 5 conducts a money creation experiment and studies the transition phase and the “new” steady state. Finally, section 6 concludes.

2. MATRICES

This section presents the matrices of the model REFORM. The first subsection presents the balance-sheet matrix. The second subsection presents the revaluation matrix. Finally, the third subsection presents the transaction-flow matrix.

2.1 Balance Sheets

This subsection presents the balance-sheet matrix for the model REFORM. The table below depicts all real and financial assets and liabilities each sector can hold. Naturally, all columns and rows sum to zero except for real assets (inventories).

Table 1. Balance-sheet matrix

	Households	Firms	Government	Central bank	Banks	Sum
Inventories		+IN				+IN
Reserves				−H	+H	0
Demand deposits	+M1				−M1	0
Time deposits	+M2				−M2	0
Bills	$+B_h$		−B	$+B_{cb}$		0
Bonds	$+BL\cdot p_{bL}$		$-BL\cdot p_{BL}$			0
Loans		−L			+L	0
Balance	−V	0	+GD	0	0	−IN
Sum	0	0	0	0	0	0

Note: Plus signs indicate assets and minus signs liabilities.

The balance-sheet matrix of REFORM is very similar to the balance-sheet matrix of INSOUT in Godley and Lavoie (2012). Households hold demand deposits, time deposits, government bills, and government bonds. Firms finance their inventories (working capital) with bank loans. Fixed capital is omitted. The government finances its budget deficit by issuing bills and bonds. The central bank buys government bills in order to issue reserves. Banks hold reserves and loans as assets and demand and time deposits as liabilities.

The only differences between REFORM and Godley and Lavoie's (2012) INSOUT model are that households do not hold cash, banks do not hold bills, and banks do not have access to central bank advances.

2.2 Revaluations

This subsection describes the revaluation matrix for the model REFORM. The table below shows the revaluation matrix.

As in Godley and Lavoie's (2012) model INSOUT, government bonds are the only asset of which value can change between periods. Bonds are long-term securities here defined as perpetuities (also called "consols") because they are never redeemed. It is assumed that each perpetuity pays the owner one unit of currency (e.g., dollar) after one period has elapsed. The one unit of currency is the coupon of the perpetuity.

Table 2. Revaluation matrix

	Households	Firms	Government	Central bank	Banks	Sum
Bonds	$+\Delta p_{bL} \cdot BL_{-1}$		$-\Delta p_{bL} \cdot BL_{-1}$			0

Note: Plus signs indicate assets and minus signs liabilities.

Bills are assumed to be short-term securities that mature within each period; therefore, their value cannot change between periods.

2.3 Transaction Flows

This subsection presents the transaction-flow matrix for the model REFORM. The table below presents the transaction-flow matrix, which captures all transactions and flows between sectors and between periods. Thus, what happens within a sector or within a period is not depicted. As usual, all the rows and columns of the transaction-flow matrix sum to zero.

Table 3. Transaction-flow matrix

	Households	Firms		Government	Central bank		Banks		Sum
		Current	Capital		Current	Capital	Current	Capital	
Consumption	$-C$	$+C$							0
Government expenditures		$+G$		$-G$					0
Change in inventories		$+\Delta IN$	$-\Delta IN$						0
[Memo: GDP]		[Y]							[Y]
Sales tax		$-T$		$+T$					0
Wages	$+WB$	$-WB$							0
Entrepreneurial profits	$+F_f$	$-F_f$							0
Bank profits	$+F_b$						$-F_b$		0
Central bank profits				$+F_{cb}$	$-F_{cb}$				0
Interest on loans		$-r_{l\text{-}1}\cdot L_{-1}$					$+r_{l\text{-}1}\cdot L_{-1}$		0
...time deposits	$+r_{m\text{-}1}\cdot M2_{-1}$						$-r_{m\text{-}1}\cdot M2_{-1}$		0
...bills	$+r_{b\text{-}1}\cdot B_{h\text{-}1}$			$-r_{b\text{-}1}\cdot B_{-1}$	$+r_{b\text{-}1}\cdot B_{cb\text{-}1}$				0
...bonds	$+BL_{-1}$			$-BL_{-1}$					0
Change in the stock of loans			$+\Delta L$					$-\Delta L$	0
...reserves						$+\Delta H$		$-\Delta H_b$	0
...demand deposits	$-\Delta M1$							$+\Delta M1$	0
...time deposits	$-\Delta M2$							$+\Delta M2$	0
...bills	$-\Delta B_h$			$+\Delta B$		$-\Delta B_{cb}$			0
...bonds	$-\Delta BL\cdot p_{bL}$			$+\Delta BL\cdot p_{bL}$					0
Sum	0	0	0	0	0	0	0	0	0

Note: Plus signs indicate sources of funds and minus signs uses of funds.

The upper part of the transaction-flow matrix is the national income part. The key features are that only sales are taxed (no income tax) and all profits are always distributed (no retained earnings). GDP is added only as a memo item for clarification. As can be read form the table, interest payments on time deposits, government bills, and government bonds are not part of GDP, but interest payments on loans are.

The lower part of the transaction-flow matrix is the flow-of-funds part which records changes in financial assets. The changes must exactly match the national income part. For example, if households have more inflows than outflows in the national income part, they are saving. In the flow-of-funds part this means that they are accumulating at least one type of asset (which is recorded with a minus sign in order to balance the column).

The national income part of the transaction-flow matrix (the upper part) is exactly the same as in Godley and Lavoie's (2012) model INSOUT. The only differences in REFORM are that there are no changes in the stocks of advances, bills held by banks, or cash held by households (as banks do not hold advances or bills and households do not hold cash) and, thus, there are, of course, no interest payments on central bank advances or on banks' holdings of bills either.

3. EQUATIONS

This section presents all the equations of the model REFORM. In total there are 76 equations of which 72 enter the model. The notation of equations follows that of Godley and Lavoie (2012). Thus, for readers of *Monetary Economics* this section should be quite easy to follow.

Capital letters denote nominal values while lower-case letters denote real (inflation accounted) values. Greek letters are parameters.

Subscript -1 refers to the end of previous period value (starting value for the current period). Subscripts s and d refer to supply and demand, respectively, in a broad sense. Subscripts f, h, g, cb, and b refer to different sectors: firms, households, government, central bank, and banks, respectively. Variables without subscript refer to realized values.

Superscript e refers to short-term expected or target value while superscript T refers to long-term target value. Short-term and long-term target values differ as short-term targets typically follow a partial adjustment process. That is, economic agents do not try to immediately (within one period) reach their long-term targets, but instead slowly adjust their short-term targets towards their long-term targets.

Suffix *A* in the numbering of equations denotes that the equation is dropped from the model either because it is redundant or it is there only for clarification. All endogenous variables are allowed to appear only once on the left-hand side of an equation.

3.1 Firms

Decisions:

$$y = s^e + (in^e - in_{-1}) \tag{F.1}$$

$$N = \frac{y}{pr} \tag{F.2}$$

$$WB = N \cdot W \tag{F.3}$$

$$UC = \frac{WB}{y} \tag{F.4}$$

$$s^e = \beta \cdot s_{-1} + (1 - \beta) \cdot s^e_{-1} \tag{F.5}$$

$$in^T = \sigma^T \cdot s^e \tag{F.6}$$

$$\sigma^T = \sigma_0 - \sigma_1 \cdot r_l \tag{F.7}$$

$$in^e = in_{-1} + \gamma \cdot (in^T - in_{-1}) \tag{F.8}$$

$$p = (1 + \tau) \cdot (1 + \varphi) \cdot NHUC \tag{F.9}$$

$$NHUC = (1 - \sigma^T) \cdot UC + \sigma^T \cdot (1 + r_l) \cdot UC_{-1} \tag{F.10}$$

$$F_f^e = \frac{\varphi}{1+\varphi} \cdot \frac{1}{1+\tau} \cdot p \cdot s^e \tag{F.11A}$$

Real output is determined by expected sales and the expected change in inventories (F.1). This yields precisely the same result as using realized values as when sales differ from expected, inventories differ exactly by the same amount in different direction. Employment is determined by real output divided by productivity (F.2). The total wage bill is employment times nominal wage (F.3), while unit costs are the wage bill divided by real output (F.4). Expected sales depend on previous realized sales and what was expected in the previous period (F.5). The long-term target for inventories is a fraction of expected sales (F.6), where the fraction depends on an autonomous term and negatively on the interest rate on loans (F.7). The short-term target for inventories follows a partial adjustment process, where the inventories are steered gradually towards their long-term target (F.8). The price level of the economy depends on a mark-up set over normal historical unit costs and sales tax rate (F.9). Normal historic unit costs depend on current and previous unit costs, including financing costs (F.10). Expected entrepreneurial profits can be written in terms of nominal expected sales, the sales tax rate, and the mark-up (F.11A), but this equation does not explicitly enter the model.

Wage inflation:

$$\omega^T = \left(\frac{W}{p}\right)^T = \Omega_0 + \Omega_1 \cdot pr + \Omega_2 \cdot \frac{N}{N_{fe}} \quad \text{(F.12)}$$

$$W = W_{-1} \cdot \{1 + \Omega_3 \cdot (\omega_{-1}^T - \omega_{-1})\} \quad \text{(F.13)}$$

Inflationary forces are introduced into the model through wages. Workers target a real wage which is positively related to productivity and employment (F.12). Workers partially adjust their nominal wage according to the discrepancy between the targeted and realized real wage in the previous period (F.13).

Realized outcomes:

$$s = c + g \quad \text{(F.14)}$$

$$S = p \cdot s \quad \text{(F.15)}$$

$$in = in_{-1} + y - s \quad \text{(F.16)}$$

$$\sigma_s = \frac{in_{-1}}{s} \quad \text{(F.17)}$$

$$IN = in \cdot UC \quad \text{(F.18)}$$

$$L_d = IN \quad \text{(F.19)}$$

$$F_f = S - T - WB + \Delta IN - r_{l-1} \cdot L_{s-1} \quad \text{(F.20)}$$

$$\pi = \frac{p - p_{-1}}{p_{-1}} \quad \text{(F.21)}$$

$$Y = p \cdot s + UC \cdot \Delta in \quad \text{(F.22)}$$

Real sales are the sum of real consumption and government expenditures (F.14), while nominal sales are simply real sales multiplied by the price level (F.15). Real inventories are inventories inherited from the previous period plus the discrepancy between real output and sales (what is produced but not sold must add to the inventory stock) (F.16). Realized fraction of inventories to sales is the end-of-period inventories divided by sales (F.17). As is customary, the nominal value of inventories is real inventories multiplied by unit costs, that is, inventories are valued at their production cost and not, for instance, at their expected sale price (F.18). Firms demand loans to finance their inventories (F.19). Realized entrepreneurial profits are nominal sales and the change in the nominal value of inventories minus taxes, wages, and interest payments on loans (F.20). Inflation is defined, as usual, as the relative change in the price level (F.21). Finally, nominal output is nominal sales plus the change in nominal inventories (F.22).

3.2 Households

Realized outcomes:

$$YD_r = WB + F + r_{m-1} \cdot M2_{h-1} + r_{b-1} \cdot B_{h-1} + BL_{h-1} \tag{H.1}$$

$$CG = (\Delta p_{bL}) \cdot BL_{h-1} \tag{H.2}$$

$$YD_{hs} = YD_r + CG \tag{H.3}$$

$$F = F_f + F_b \tag{H.4}$$

$$V = V_{-1} + YD_{hs} - C \tag{H.5}$$

$$V = M1_h + M2_h + B_h + p_{bL} \cdot BL_h \tag{H.6A}$$

$$yd_r = \frac{YD_r}{p} - \pi \cdot \frac{V_{-1}}{p} \tag{H.7}$$

$$yd_{hs} = yd_r + \frac{CG}{p} \tag{H.8}$$

$$yd_{hs} = c + \Delta v \tag{H.9A}$$

$$v = \frac{V}{p} \tag{H.10}$$

Unlike with firms, I describe the equations for households starting from realized outcomes and only then proceeding to decisions. Regular disposable income includes wages, profits, and interest revenue on time deposits, bills, and bonds (H.1). Capital gains are the change in the price of bonds multiplied by the end-of-period amount of bonds (H.2). Haig-Simons nominal disposable income includes regular disposable income and capital gains (H.3). Total profits distributed to households consist of entrepreneurial profits and banks' profits (H.4). Notice that profits are always distributed in full and, therefore, there are no retained earnings.

Wealth of households is the wealth inherited from the previous period plus Haig-Simons disposable income minus consumption (H.5). Wealth of households could also be written as the sum of all financial assets (H.6A), but as will be later seen this equation is saved for another purpose. Real regular disposable income is nominal regular disposable income minus the inflation tax on real wealth (H.7). Similarly as before, Haig-Simons real disposable income is real regular disposable income plus real capital gains (H.8), which is the same as real consumption plus the change in real wealth (H.9A). Real wealth is, of course, nominal wealth divided by the price level (H.10).

Decisions:

$$c = \alpha_0 + \alpha_1 \cdot yd_r^e + \alpha_2 \cdot v_{-1} \tag{H.11}$$

$$yd_r^e = \varepsilon \cdot yd_{r-1} + (1-\varepsilon) \cdot yd_{r-1}^e \tag{H.12}$$

$$C = p \cdot c \tag{H.13}$$

$$YD_r^e = p \cdot yd_r^e + \pi \cdot \frac{V_{-1}}{p} \tag{H.14}$$

$$V^e = V_{-1} + (YD_r^e - C) \tag{H.15}$$

Households make a two-stage decision following Keynes (1936, 166). First, they decide how much they will save (by deciding how much they spend). Second, they decide how to allocate their wealth (portfolio equations below). Real consumption of households depends on expected real regular disposable income, real wealth of previous period, and an autonomous term (H.11). In turn, expected real regular disposable income depends on previous real regular disposable income and what was previously expected (H.12). Nominal consumption is real consumption times the price level (H.13). However, expected nominal regular disposable income depends on expected real regular disposable income times the price level but also on inflation revenue on real wealth (H.14). Putting things together, nominal expected wealth depends on previous wealth plus expected saving (expected nominal regular disposable income minus consumption) (H.15).

Demand for assets (portfolio equations): [1]

$$\frac{M1_d}{V^e} = \lambda_{10} + \lambda_{12} \cdot r_m + \lambda_{13} \cdot r_b + \lambda_{14} \cdot r_{bL} + \lambda_{15} \cdot \frac{YD_r^e}{V^e} \tag{H.16}$$

$$\frac{M2_d}{V^e} = \lambda_{20} + \lambda_{22} \cdot r_m + \lambda_{23} \cdot r_b + \lambda_{24} \cdot r_{bL} + \lambda_{25} \cdot \frac{YD_r^e}{V^e} \tag{H.17}$$

$$\frac{B_d}{V^e} = \lambda_{30} + \lambda_{32} \cdot r_m + \lambda_{33} \cdot r_b + \lambda_{34} \cdot r_{bL} + \lambda_{35} \cdot \frac{YD_r^e}{V^e} \tag{H.18}$$

$$\frac{p_{bL} \cdot BL_d}{V^e} = \lambda_{40} + \lambda_{42} \cdot r_m + \lambda_{43} \cdot r_b + \lambda_{44} \cdot r_{bL} + \lambda_{45} \cdot \frac{YD_r^e}{V^e} \tag{H.19}$$

Now, we arrive to the second stage of Keynes's (1936, 166) decision-making process in which households decide how they allocate their wealth. Demand for various assets is depicted in the portfolio equations above following Tobinesque principles. Adding-up constraints, emphasized by Tobin (1969), are satisfied. [2]

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[1] The rates of return on demand deposits and λ_{i1} associated to them are dropped from portfolio equations as the rate of return on demand deposits is assumed to be zero.

[2] Vertical conditions are: $\sum \lambda_{i0} = 1$, $\sum \lambda_{i1} = 0$, $\sum \lambda_{i2} = 0$, $\sum \lambda_{i3} = 0$, and $\sum \lambda_{i4} = 0$. Symmetry conditions (which together with vertical conditions also satisfy horizontal conditions) are: $\lambda_{ij} = \lambda_{ji}, for\ all\ i \neq j$.

The fraction of demand deposits to expected total wealth depends positively (the coefficient is positive) on an autonomous and a transaction term (first and last term on the right-hand side) and negatively on rates of return on other assets (H.16). Although cash is not explicitly included, it can be thought to be implicitly included in demand deposits as under FRB they are analytically exactly the same: they are used for transactions, they do not earn interest, they cannot fund bank lending, and they provide a completely safe store of value.

In turn, the fraction of time deposits depends positively on an autonomous term and its own rate of return (first two terms on the right-hand side) and negatively on rates of return on other assets and transactions (H.17). Similarly to time deposits, the fraction of bills depends positively on an autonomous term and its own rate of return and negatively on rates of return on other assets and transactions (H.18). As with time deposits and bills, the fraction of bonds also depends positively on an autonomous term and its own rate of return and negatively on rates of return on other assets and transactions (H.19).

Realized asset holdings:

$$M1_h = H_s - (M2_h - L_s) \tag{H.20}$$

$$M2_h = M2_d \tag{H.21}$$

$$BL_h = BL_d \tag{H.22}$$

$$B_h = V - M1_h - M2_h - p_{bL} \cdot BL_h \tag{H.23}$$

$$B_h = B_s - B_{cb} \tag{H.24A}$$

$$r_b = \frac{\frac{B_h}{V^e} - \lambda_{30} - \lambda_{32} \cdot r_m - \lambda_{34} \cdot r_{bL} - \lambda_{35} \cdot \frac{YD_r^e}{V^e}}{\lambda_{33}} \tag{H.25}$$

Although portfolio equations determine the demand for assets, the realized holdings of assets typically differ as realized wealth and income usually differ from what was expected. As in Godley and Lavoie (2012), demand deposits act as a “buffer” which reconciles the discrepancy between expected and realized outcomes.

The realized holding of demand deposits is determined by central bank reserves minus the difference between time deposits and loans (H.20). This can also be read from banks’ balance sheet. The idea behind this is that demand deposits are initially equal to reserves. However, households can invest in time deposits offered by banks, which reduces demand deposits held by households. Banks’ can now use these funds to make loans. As banks make loans, demand deposits are returned into circulation (thus, bank lending does not create money under FRB). If banks do not make loans as much as households make time deposits, demand deposits do not get returned into circulation and, therefore, their amount is less than reserves.

Also Keynes (1936, 110–11) pointed out that the demand for money (liquidity preference) is irrelevant in the sense that it cannot directly affect the amount of money:

> "The concept of *hoarding* may be regarded as a first approximation to the concept of *liquidity-preference*. […] For the amount of hoarding must be equal to the quantity of money […]. All that the propensity of the public towards hoarding can achieve is to determine the rate of interest [and rates of return on financial assets more generally] at which the aggregate desire to hoard becomes equal to the available cash." (Italics in original)

Time deposits and bonds are determined more straightforwardly. The realized holdings of time deposits and bonds equal their demand (H.21 and H.22).

The realized amount of bills held by households is total wealth minus other financial assets (H.23). This equation is simply (H.6A) rearranged. However, the amount of bills left for households is entirely determined by the decisions of the government (how many bills it issues) and the central bank (how many bills it buys to monetize government debt) (H.24A). In other words, households are the residual buyer of bills. Nevertheless, households cannot be forced to hold bills against their will.

In order to ensure that households buy exactly all the remaining bills, the interest rate on bills must be endogenous. Thus, the interest rate on bills is determined by the portfolio equation solved for the bill rate instead of the amount of bills (H.25). In the model the bill rate[3] corresponds to the main policy rate today (e.g., the federal funds rate in the US, the base rate in the UK, and the rate of main refinancing operations in the euroarea).

The redundant equation is the equation indicating that households are the residual buyer of bills (H.24A). Although equation (H.24A) does not explicitly enter the model, it gives exactly the same result as (H.23). The equation is dropped from the model as otherwise the model would be overdetermined. This means that all the other equations together already imply the dropped equation.

[3] Notice that, for simplification, the main rate is the bill rate rather than more realistically the inter-bank overnight rate.

3.3 Government

Fiscal policy:

$$T = \tau \cdot (S - T) = S \cdot \frac{\tau}{1+\tau} \tag{G.1}$$

$$G = p \cdot g \tag{G.2}$$

$$PSBR = G + r_{b-1} \cdot B_{s-1} + BL_{s-1} - (T + F_{cb}) \tag{G.3}$$

$$B_s = B_{s-1} + PSBR - (\Delta BL_s) \cdot p_{bL} \tag{G.4}$$

$$BL_s = BL_h \tag{G.5}$$

$$r_{bL} = \bar{r}_{bL} \tag{G.6}$$

$$p_{bL} = \frac{1}{r_{bL}} \tag{G.7}$$

$$GD = B_s + p_{bL} \cdot BL_s \tag{G.8}$$

$$GD_{EDP} = B_h + p_{bL} \cdot BL_s \tag{G.9}$$

The government collects taxes according to the sales tax rate it sets exogenously (G.1). Nominal government expenditures are simply real government expenditures, which are set exogenously, multiplied by the price level (G.2).

The government budget deficit, that is, the public sector borrowing requirement (PSBR) is the difference between total outlays (including spending and interest payments on bills and bonds) and total income (including taxes and central bank profits) (G.3). The government issues (redeems) bills to finance the part of the budget deficit (surplus) that is not financed by the issuance of government bonds (G.4). The government lets households decide how many bonds they want to hold (G.5) with the interest rate set exogenously by the government (G.6). Alternatively, as with bills, the government could decide how many bonds it wants to issue and let the bond rate to be determined on the market. The price of bonds is simply the coupon (one unit of currency) divided by the bond rate (G.7).

Gross government debt[4] is simply the value of outstanding bills and bonds (G.8). Consolidated government debt is the value of bills and bonds held by non-public entities (G.9). Put differently, consolidated government debt is gross government debt minus intra-government debt (in this case bills held by the central bank). Consolidated government debt is also known as excessive deficit

[4] The market value of government debt can differ from its recorded historical value, which is generally reported by officials, to the extent that bond prices have appreciated or depreciated. However, as the bond rate is set exogenously, there cannot be any changes in bond prices and, thus, in this instance the market value of government debt also equals its recorded historical value.

procedure (EDP) government debt as it is used for calculating the Maastricht criteria in the EU. This means that it is the "official" figure for government debt in the EU.

3.4 Central Bank

Monetary policy:

$$H_s = B_{cb} \tag{C.1}$$

$$B_{cb} = \bar{B}_{cb} \tag{C.2}$$

$$r_h = 0 \tag{C.3}$$

$$F_{cb} = r_{b-1} \cdot B_{cb-1} \tag{C.4}$$

The central bank can greatly influence the money supply through reserves. As can be directly read from the balance-sheet matrix, the central bank sets the amount of reserves by determining how many bills it holds (C.1). The simplest monetary policy rule is to keep the amount of bills constant, that is, the amount of bills is exogenous (C.2). Alternative monetary policy rules are worth considering but they are not the topic of this paper.

As it is assumed that interest is not paid on reserves (C.3), the profit of the central bank is determined by the interest payments it receives on bills from the government (C.4).

3.5 Banks

Liquidity:

$$H_{min} = \rho_1 \cdot M1_s + \rho_2 \cdot M2_s \tag{B.1}$$

$$H_{bd} = H_s \tag{B.2}$$

$$BLR = \frac{H_s}{M1_s} \tag{B.3}$$

The full-reserve requirement is incorporated by setting the reserve requirement for demand deposits ρ_1 equal to 1 (B.1). There is no reserve requirement for time deposits so ρ_2 is equal to zero. Banks demand whatever reserves they are supplied with (B.2). The bank liquidity ratio is the ratio between reserves and demand deposits (B.3). Under FRB this ratio has to be at least 1.

Monetary and credit aggregates:

$$M1_s = M1_h \quad \text{(B.4)}$$

$$M2_s = M2_h \quad \text{(B.5)}$$

$$L_s = L_d \quad \text{(B.6)}$$

Banks supply both demand and time deposits in whatever amount is required (B.4 and B.5). As previously described, the amount of demand deposits can be read from banks' balance sheets (H.20). The amount of time deposits is completely determined by their demand (H.16 and H.21). Banks also accommodate the demand for loans for all creditworthy firms (B.6).

Determination of interest rates:

$$r_m = r_{m-1} + \Delta r_m \quad \text{(B.7)}$$

$$\Delta r_m = \varsigma_m \cdot (z_1 - z_2) \quad \text{(B.8)}$$

$$z_1 = 1, iff\ BLR_{-1} < BLR_{bot} \quad \text{(B.9)}$$

$$z_2 = 1, iff\ BLR_{-1} > BLR_{top} \quad \text{(B.10)}$$

$$r_l = r_{l-1} + \Delta r_l + \Delta r_b \quad \text{(B.11)}$$

$$\Delta r_l = \varsigma_l \cdot (z_3 - z_4) \quad \text{(B.12)}$$

$$z_3 = 1, iff\ BPM < BPM_{bot} \quad \text{(B.13)}$$

$$z_4 = 1, iff\ BPM > BPM_{top} \quad \text{(B.14)}$$

$$BPM = \frac{F_b + F_{b-1}}{M1_{s-1} + M1_{s-2} + M2_{s-1} + M2_{s-2}} \quad \text{(B.15)}$$

$$F_b = r_{l-1} \cdot L_{s-1} - r_{m-1} \cdot M2_{s-1} \quad \text{(B.16)}$$

Banks can set the interest rates on time deposits and loans, while the interest rate on demand deposits is assumed to be zero (which is also very much in line with the real world today). Banks follow a partial adjustment process when setting the interest rate on time deposits (B.7 and B.8). If the bank liquidity ratio falls below its desired level in the previous period, banks increase the deposit rate to attract more time deposits (B.9). As households invest in time deposits, their demand deposits get reduced and this increases the bank liquidity ratio. Symmetrically, when the bank liquidity ratio increases above its desired level in the previous period, banks decrease the deposit rate to reduce the amount of time deposits (B.10). As long as the bank liquidity ratio stays within its desired range, banks do not alter the interest rate on time deposits.

Banks set the interest rate they charge on loans to ensure a sufficient profit margin. When setting the loan rate, banks follow a partial adjustment process as well as the bill rate (B.11 and B.12).

Now, when the bank profit margin is below its desired level, banks increase the interest rate they charge on loans (B.13). Symmetrically, when the bank profit margin is above its desired level, banks decrease the interest rate on loans (B.14). Unlike in mainstream economics, banks do not maximize profits (at least in the short run). Godley and Lavoie (2012, 340) justify this by the banks' fear of government regulation or consumer outrage. The bank profit margin is determined by average profits divided by the sum of average demand and time deposits (B.15). Finally, banks' profits are determined by the difference between the interest payments they receive from loans and the interest payments they make on time deposits (B.16). In this model real rates are meaningless but they could be used instead of nominal rates. [5]

4. STEADY STATE

In the simplest SFC models it is possible to obtain a determinate analytical solution for a steady state. However, in more complex models, such as REFORM, obtaining a determinate steady-state solution analytically becomes impossible as the model is path-dependent. It can be said that the model exhibits deep endogeneity as the steady state depends on the past history. The steady-state solution for each set of parameters and initial values can, however, be obtained through simulation.

The steady state of REFORM is stationary as there is no productivity growth or other forces driving economic growth. That is, there is no push for economic growth or collapse under FRB and, therefore, it is a zero-growth economy.

In an FRB system with no economic growth both full employment and zero inflation are achieved. In other words, FRB does not in itself lead to a fall in employment. In addition, it does not cause inflationary—let alone hyperinflationary—nor deflationary tendencies.

In the steady state there is no increase in either public nor private debt. Servicing debt is also entirely possible. Thus, under FRB there is no push for ever increasing (nominal) debt. [6]

[5] Real rates can be defined as $rr_h = -\frac{\pi}{1+\pi} = \frac{1+0}{1+\pi} - 1$, $rr_m = \frac{1+r_m}{1+\pi} - 1$, $rr_l = \frac{1+r_l}{1+\pi} - 1$, $rr_b = \frac{1+r_b}{1+\pi} - 1$ and $rr_{bL} = \frac{1+r_{bL}}{1+\pi} - 1$.

[6] Hoarding by firms or banks (in the sense of retained earnings) is, however, not allowed in the model. If this assumption were relaxed, the conclusion might be different.

There is no shortage of credit under FRB either. Banks are able to supply all loans that are demanded by creditworthy borrowers. If needed, banks adjust the interest rate on time deposits to attract enough deposits to fund the loans.

In the steady state time deposits exceed demand deposits. Although under FRB this might first sound a bit weird, it is completely possible as the same money (demand deposits) can be re-lent. For instance, if households acquire time deposits, their demand deposits are reduced by the same amount. However, banks can lend these demand deposits for firms. Again, firms can pay wages for households with these demand deposits. Thus, the same demand deposits households used for acquiring time deposits can be returned back to them through firms and used again to acquire more time deposits or other assets.

The existence of a steady state in an FRB system is already an argument for FRB as it implies that the state of issues can be attained indefinitely. However, it is possible that the system becomes unstable as soon as something changes. Next, in order to address this issue let us conduct a money creation experiment with the model REFORM.

5. MONEY CREATION EXPERIMENT

Under FRB money is created through government spending, as has been proposed by Jackson and Dyson (2012) and Sigurjonsson (2015), among others. In the experiment with REFORM the central bank buys bills worth 15, which increases reserves from 50 to 65, and the government increases its spending by 15 for one period and then spending returns to its previous value.

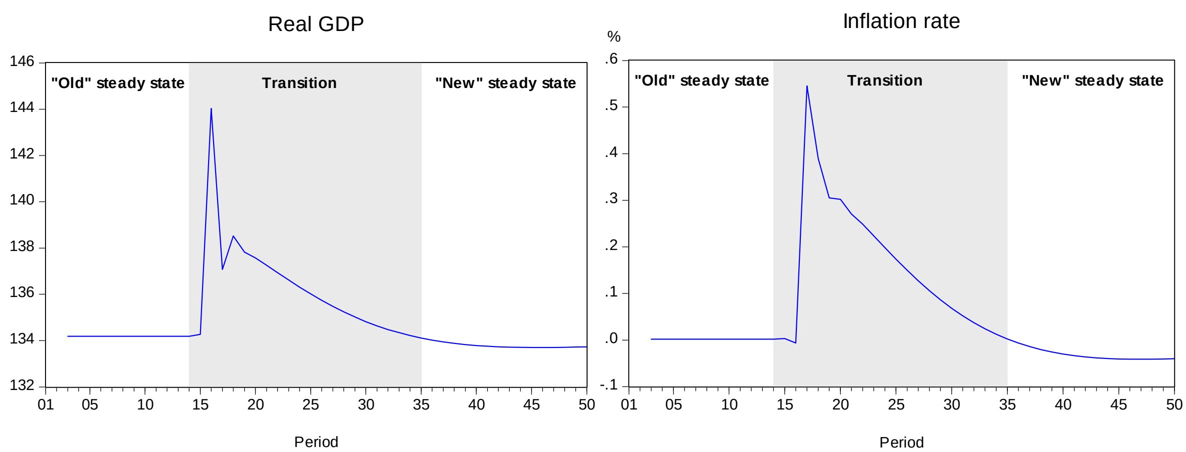
The money creation experiment takes place in period 15. In the figures below an area from period 15 to 34 is shaded to depict the transition phase from the "old" steady state to the "new" steady state. For clarification, the following subsections use notation *t=0* for indicating period 15, that is, exactly when money creation takes place, *t=1* for the following period, etc.

When interpreting the figures it is important to take the scale into account as the figures are scaled appropriately to depict the movements of variables. Therefore, depending on the scale, a radical-looking movement can be insignificant and, vice versa, a minor-looking movement can be very significant.

5.1 GDP and Inflation

As can be seen from Figure 1, below, both real GDP and inflation speed up temporarily after money is created. The level of real GDP peaks at a 7% higher level and then returns to its new steady state value which is exactly the same as the "old" steady state. The period-on-period inflation rate peaks at 0.5% before returning to zero in the new steady state. In the peak the price level is 3% higher, but as inflation is very slightly negative for multiple periods after the transition phase, the price level also ultimately converges to its "old" steady-state value.

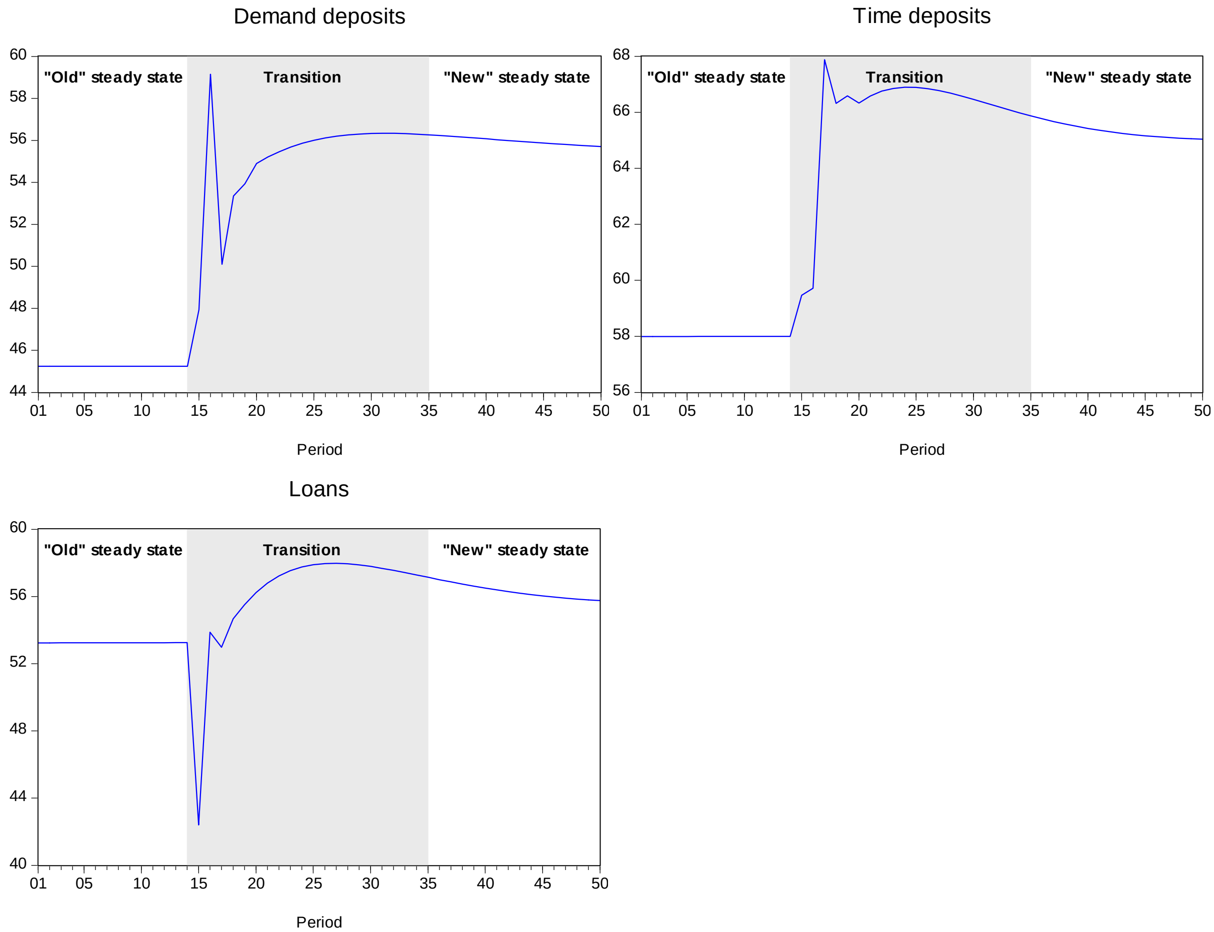
Figure 1. Output and inflation



5.2 Monetary and Credit Aggregates

As equation (H.20) showed, the amount of demand deposits held by households depends on reserves and the discrepancy between time deposits and loans. In the experiment reserves are increased from 50 to 65. Should time deposits and loans stay constant or move by the same amount in the same direction, changes in demand deposits would exactly match changes in reserves. However, as figure 2 (below) shows, this is not the case, as households will reallocate their wealth and firms will adjust their demand for loans.

Figure 2. Deposits and loans



In period 15 (t=0), exactly when reserves are increased by 15, demand deposits increase by only 3. The reason for this is that the gap between time deposits and loans widens by 13: time deposits increase by 2 and loans fall by 11 (the numbers do not exactly add up because of rounding). The main reason why the gap widens is that firms demand fewer loans as they have fewer inventories that need to be financed. Inventories drop sharply as sales easily exceed expected sales. Particularly for this reason, an increase in reserves does not instantly translate into an equal increase in demand deposits.

In period 16 (t=1) monetary policy seems to transmit more effectively as demand deposits increase by 11 (compared to the "old" steady-state total increase of 14, which is almost equal to the increase of reserves by 15). Demand deposits peak as loans have returned close to their "old" steady-state value as firms adjust their expected sales upwards in order to recover their inventories. As time deposits do not change, the gap between time deposits and loans shrinks by 11, which exactly matches the increase in demand deposits.

In period 17 (t=2) households continue to rebalance their asset portfolios which leads to a sharp decline in demand deposits. As households increase their time deposits by 8 and the demand for loans decreases by 1, the drop in demand deposits is 9. In the following transition periods (t=3+) demand deposits recover as time deposits slightly decrease while loans increase.

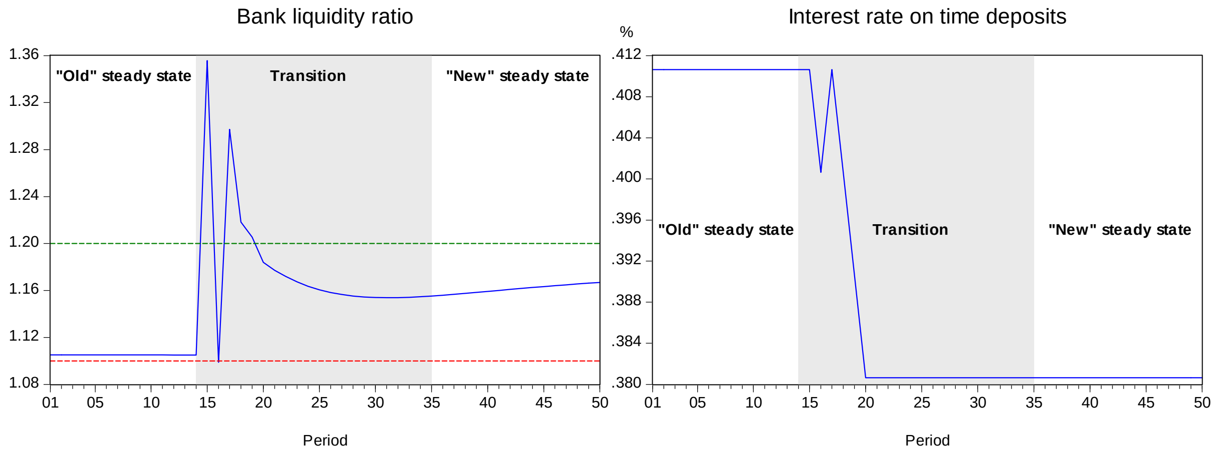
Finally in the "new" steady state, all variables level off (there are only very minor movements as variables continue to converge to their ultimate values). In the end, compared to the "old" steady state, demand deposits increased by 10, time deposits by 7, and loans by 2. To put it briefly, increasing reserves by 15 translated into an increase of 10 in demand deposits.

5.3 Bank Liquidity and Deposit Rate

The bank liquidity ratio was defined by equation (B.3) as reserves relative to demand deposits. Under FRB this ratio has to be at least 1 to satisfy the liquidity requirement. Otherwise, banks are in a liquidity crisis.

Banks can indirectly influence their liquidity ratio by changing the interest rate they offer on time deposits. This may also partly help to explain the above-observed fluctuations in time deposits and, subsequently, in demand deposits. As can be seen from figure 3, below, banks target a liquidity ratio between 1.1 and 1.2 where they do not alter the interest rate on time deposits.

Figure 3. Bank liquidity and deposit rate



In period 15 (t=0) banks receive reserves worth 15 which increases their liquidity ratio over the preferred upper target of 1.2. In the next period (t=1) banks react to this by reducing the interest rate on time deposits to curb households' demand for time deposits. Consequently, households end up with significantly more demand deposits (although, as was seen in figure 2, above, this is mainly because of loans recover). The increase in demand deposits again drops the bank liquidity ratio below its lower target.

In period 17 (t=2) banks again react to this, but this time they increase the deposit rate back to its "old" steady-state value. As was also shown figure 2, above, households strongly react to this by increasing their holding of time deposits. This, together with no significant change in firms' demand for loans, reduces demand deposits strongly. Now the bank liquidity ratio again exceeds its upper target.

In periods 18–20 (t=3–5) banks react by reducing the deposit rate each period. In the following periods (t=6+) the system starts to find its new steady state as the liquidity ratio is within its target range and, consequently, banks do not alter the deposit rate anymore. Compared to the "old" steady state the interest rate on time deposits is 0.03% points lower.

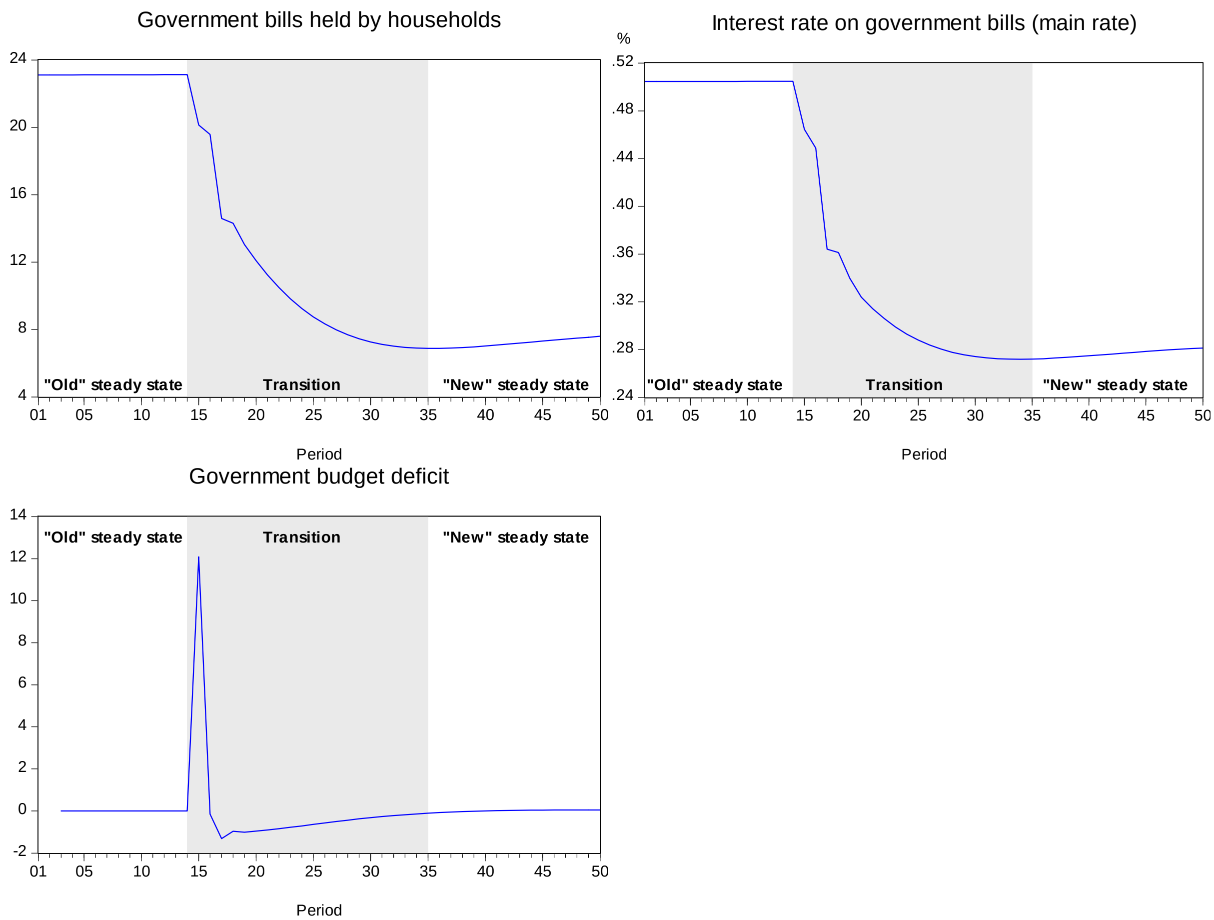
In the experiment the money supply is increased by 30% to study what happens when the targeted bank liquidity ratio is exceeded and when unusually large changes in the money supply take place. As was seen above, when the bank liquidity ratio target is exceeded, banks can adjust the interest rate on time deposits in an appropriate manner to provide all deposit and credit functions demanded.

At any moment there is no shortage of credit. In the end, the interest rate on time deposits dropped by mere 0.03 % points even though the money supply was increased dramatically. As will be discovered next, in contrast to what some claim, unusually large changes in the money supply do not even lead to an excessively volatile interest rate on bills (the main rate in the model) under FRB.

5.4 Bills and Main Rate

As new money is created in the experiment, the central bank buys bills worth 15, the government increases its spending by 15 for one period, and then government spending returns to its previous value. Intuitively, the amount of bills held by households (thus also the bill rate) should stay constant as households are the residual buyer of bills. Surprisingly, however, Figure 4, below, shows that bills held by households decrease—and they keep on decreasing over multiple periods even after money has already been created.

Figure 4. Bills, main rate, and government budget deficit



The counterintuitive result can be explained as follows. As some of the government spending also increases tax revenue for the government, the government budget deficit is less than 15, that is, less than the increase in government spending. Thus, the government does not need to issue new bills worth 15 but only 12. This leads to the situation where households' holding of bills is reduced by 3 in period 15 (t=0) as the central bank buys 15 of them. As households are left with fewer bills, the interest rate on bills (the main rate) drops slightly to reconcile demand with supply.

In periods 16 and 17 (t=1–2) households reallocate their wealth and increase their holdings of bonds of which the interest rate remains unchanged (not depicted in a figure). This further reduces the amount of bills households hold as government debt can be restructured by households; that is, an increase in bonds means an equal decrease in bills (given the amount of government debt), as can also be read from equation (G.4). The reallocation of household wealth also contributes to the decrease in the bill rate.

From period 16 onwards (t=1+), the government runs a small but persistent budget surplus which also partly reduces bills and bonds held by households. This government surplus is the third force pushing the bill rate down.

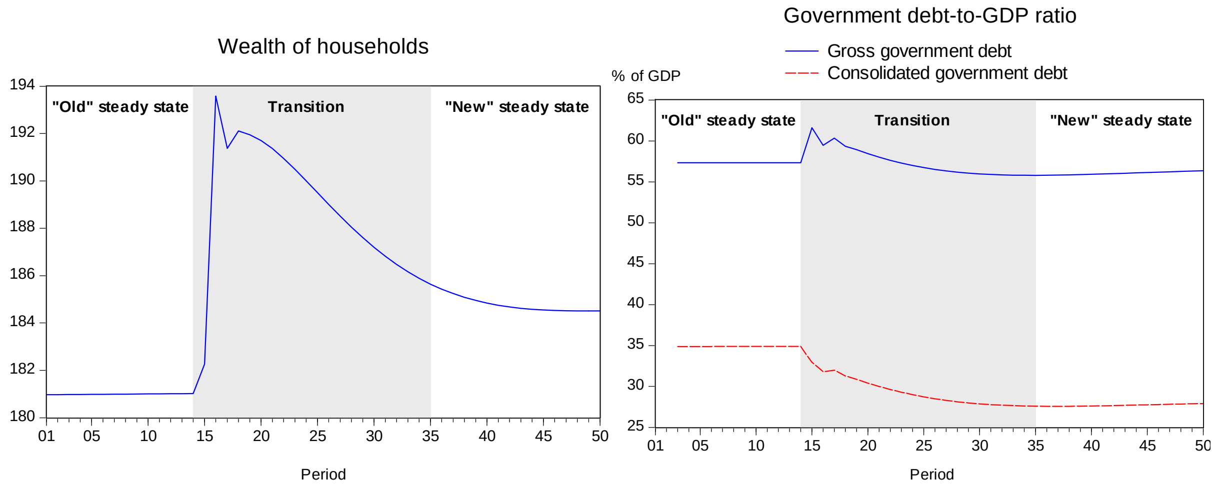
Finally, the economy finds the "new" steady state where households have reduced their holding of bills by 16 and the interest rate on bills has dropped from 0.5% to 0.28%. Although the money supply was increased quite dramatically by 30%, it did not lead to any noteworthy volatility in the bill rate—contrary to what is claimed by some economists. Instead, it leads to a smooth and relatively small change in the bill rate on its path to its "new" steady-state value.

5.5 Private Wealth and Public Debt

As post-Keynesians often emphasize, relying on an accounting identity, public sector debt increases private sector wealth. The net financial wealth of the whole private sector (comprising households, firms, and banks) is exactly equal to gross government debt.

Figure 5, (below) shows the development of household wealth and government debt. Household wealth closely matches the development of gross government debt. The small discrepancy is explained by loans granted to firms (see figure 2). The net financial wealth of households (which is also gross, as there are no household liabilities in the model) is exactly equal to gross government debt plus loans (inventories are *real* wealth and therefore the net *financial* wealth of firms is negative).

Figure 5. Household wealth and government debt



Although household wealth is only slightly higher in the "new" steady state, the composition of wealth has greatly changed. As was seen in previous subsections, demand deposits, time deposits and bonds contributed positively to the increase in household wealth. The decrease in bills held by households contributed negatively.

As figure 4 showed, the government runs a brief but large budget deficit followed by a persistent but small budget surplus. Figure 5Figure 5, above, shows how this translates into gross and consolidated government debt relative to GDP. Not surprisingly, gross government debt first increases and then slowly reverts back. As previously pointed out, this also represents the development of the net financial wealth of the whole private sector.

However, more noteworthy is the smooth and permanent reduction in consolidated government debt. It has at least three important implications. First, it reduces interest payments on government debt which can be used otherwise to service the public interest. Second, in the long run after more and more money was created the government could also become "debt-free," if so decided, in the sense that it would not be indebted towards any private agent.

Third, the reduction in consolidated government debt offers a practical way out of the eurocrisis. In the EU consolidated government debt (known as EDP debt) is used for calculating the Maastricht criteria. Therefore, new money creation by the European Central Bank (ECB) could offer a way to reduce government debt *and* offer much needed fiscal stimulus. The exact means of how new money would be distributed should be decided politically. For instance, new money could be distributed among euroarea member states in relation to their population.

This section experimented with the REFORM model to study how new money creation under FRB would influence the economy. In the model, money creation took place through government spending. Jackson and Dyson (2012) and Sigurjonsson (2015) give four alternative ways to create money under FRB: reduce taxes; repay government debt; pay dividend for citizens; and lend it to banks on the condition that it will be on-lent to the real economy. These alternative ways to create money were not considered, but they offer a good basis for further study.

6. CONCLUSIONS

This paper builds a simple, yet coherent and complete, SFC model of FRB called REFORM. In the steady state an FRB system accommodated a zero-growth economy, that is, there was no push for economic growth or collapse. Full employment and zero inflation were also achieved.

In addition, a money creation experiment was conducted with the model REFORM. An increase in central bank reserves translated into a two-thirds increase in demand deposits. Money creation through government spending led to a temporary increase in real GDP and inflation. Surprisingly, it also led to a permanent reduction in consolidated government debt.

The permanent reduction in consolidated government debt had at least three important implications. First, it could reduce interest payments on government debt which could be used otherwise. Second, eventually the government could become “debt-free” in the sense that it would not be indebted towards any private agent. Third, it could offer a practical way out of the eurocrisis. As in the EU consolidated government debt (known as EDP debt) is used for calculating the Maastricht criteria, new money creation could reduce government debt *and* offer much needed fiscal stimulus.

The claims that FRB would lead to a credit crunch or excessively volatile interest rates were found to be baseless. At all times banks could grant all demanded loans to creditworthy borrowers by adjusting the interest rate on time deposits. An unusually large change in the money supply only led to smooth and relatively small changes in interest rates.

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APPENDIX: LIST OF VARIABLES

Table 4. List of endogenous variables

Symbol	**Description**
B_{cb}	Bills held by central bank
B_d	Demand for bills
B_h	Bills held by households
B_s	Supply of bills
BL_d	Demand for bonds
BL_h	Bonds held by households
BL_s	Supply of bonds
BLR	Bank liquidity ratio
BPM	Bank profit margin
c	Real consumption
C	Nominal consumption
CG	Capital gains
F	Total profits distributed to households
F_b	Profits of banks
F_{cb}	Profits of central bank
F_f	Entrepreneurial profits
F_f^e	Expected entrepreneurial profits
G	Nominal government expenditures
GD	Gross government debt
GD_{EDP}	Consolidated government debt (EDP debt)
H_{bd}	Demand for reserves
H_{min}	Required reserves from banks
H_s	Supply of reserves
in	Real inventories
in^e	Real short-term target inventories
in^T	Real long-term target inventories
IN	Nominal inventories
L_d	Demand for loans
L_s	Supply of loans

$M1_d$	Demand for demand deposits
$M1_h$	Demand deposits held by households
$M1_s$	Supply of demand deposits
$M2_d$	Demand for time deposits
$M2_h$	Time deposits held by households
$M2_s$	Supply of time deposits
N	Employment level
$NHUC$	Normal historic unit costs
p	Price level
p_{bL}	Price of bonds
$PSBR$	Public sector borrowing requirement (government budget deficit)
r_b	Interest rate on bills
r_{bL}	Interest rate on bonds
r_h	Interest rate on reserves
r_l	Interest rate on loans
r_m	Interest rate on time deposits
s	Real sales
s^e	Real expected sales
S	Nominal sales
T	Nominal sales taxes
UC	Nominal unit costs
v	Real wealth of households
V	Nominal wealth of households
V^e	Expected nominal wealth of households
W	Nominal wage
WB	Nominal wage bill
y	Real output
Y	Nominal output
yd_{hs}	Real Haig-Simons disposable income
yd_r	Real regular disposable income
yd_r^e	Expected real regular disposable income
YD_{hs}	Nominal Haig-Simons disposable income

YD_r	Nominal regular disposable income
YD_r^e	Expected nominal regular disposable income
z_1	Dichotomic variable related to bank liquidity ratio
z_2	Dichotomic variable related to bank liquidity ratio
z_3	Dichotomic variable related to bank profit margin
z_4	Dichotomic variable related to bank profit margin
σ_s	Real inventories-to-sales ratio
σ^T	Real long-term target inventories-to-sales ratio
π	Price inflation
ω	Real wage
ω^T	Real long-term target wage

Table 5. List of exogenous variables

Symbol	Description
$\bar{B}_{cb}$	Amount of bills central bank decides to hold
BLR_{bot}	Bottom range of bank liquidity ratio
BLR_{top}	Top range of bank liquidity ratio
BPM_{bot}	Bottom range of bank profit margin
BPM_{top}	Top range of bank profit margin
g	Real government expenditures
N_{fe}	Full employment level
pr	Productivity level
$\bar{r}_{bL}$	Interest rate set on bonds by government

Table 6. List of parameters

Symbol	Description
α_0	Autonomous consumption
α_1	Propensity to consume out of regular income
α_2	Propensity to consume out of past wealth
β	Reaction parameter related to sales expectations
γ	Partial adjustment parameter related to target inventories
ε	Reaction parameter related to income expectations
ς_l	Reaction parameter related to changes in loan rate
ς_m	Reaction parameter related to changes in deposit rate
λ	Reaction parameters in portfolio equations
ρ_1	Compulsory reserve ratio on demand deposits
ρ_2	Compulsory reserve ratio on time deposits
σ_0	Reaction parameter related to target inventories-to-sales ratio
σ_1	Reaction parameter related to target inventories-to-sales ratio
τ	Sales tax rate
φ	Costing margin in pricing
Ω_0	Reaction parameter related to real wage targeting
Ω_1	Reaction parameter related to real wage targeting
Ω_2	Reaction parameter related to real wage targeting
Ω_3	Reaction parameter related to nominal wage setting